

WHAT IS CLAIMED IS:

1. A light controlling film, the film having a first surface and a second surface, comprising:

5           a polymerized polymer network, the polymer network varying spatially in a direction normal to the first surface, the polymerized polymer network comprising:  
10           a crosslinked high molecular weight polymeric material; and  
              a low molecular weight polymeric material, wherein the high molecular weight and the low molecular weight form a material having cholesteric liquid crystal (CLC) order, the CLC order oriented with respect to the first and the second surfaces, the pitch of the CLC order varying non-linearly in a direction perpendicular to the first surface, and  
15           wherein light having a first polarization and a broad bandwidth incident on the first surface is substantially reflected from the film, and wherein light having a second polarization and the broad bandwidth incident on the first surface is not substantially reflected from the film, and wherein an electric field impressed in the film controls the reflection of light having the first polarization when the electric field has a  
20           component in a direction normal to the first surface.

2. The light controlling film of claim 1, wherein the crosslinked high molecular weight polymeric material is less than 20% by weight of the film.

25           3. The light controlling film of claim 2, wherein the crosslinked high molecular weight polymeric material is less than 15% by weight of the film.

4. The light controlling film of claim 3, wherein the crosslinked high molecular weight polymeric material is less than 10% by weight of the film.

5. The light controlling film of claim 1, further comprising electrically conducting material adjacent to the first surface for impressing an electric field in the film, the electrically conducting material transmitting the light having the broad bandwidth and the first polarization.

10 6. The apparatus of claim 5, further comprising a second electrically conducting material adjacent to the second surface, wherein a voltage applied between the first and the second electrically conducting material impresses an electric field on in the film.

15 7. The apparatus of claim 6, wherein the second electrically conducting material transmits light having the first bandwidth.

20 8. The apparatus of claim 6, wherein the first polarization is a circular polarization.

25 9. The apparatus of claim 8, further comprising a transparent quarter wave retardation plate in close proximity to the first surface, whereby linearly polarized light incident on the transparent quarter wave retardation plate is controllably reflected.

10. The apparatus of claim 5, further comprising a means for applying an electric field in the film, the electric field varying spatially over the first surface, whereby polarized light is controllably reflected for

display purposes.

11. The apparatus of claim 5, further comprising a means for applying an electric field in the film, the electric field having a controllable bias field and a controllable adjustment field, whereby the reflectivity of polarized light may be substantially changed by changing the controllable adjustment field.

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12. The apparatus of claim 5, further comprising optical communication means, whereby the light in the optical communication means is controlled.

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13. The apparatus of claim 5, further comprising means for directing light on to the first surface, and means for receiving reflected light from the first surface, whereby polarized light with a controllable bandwidth produced in the means for receiving reflected light.

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14. The apparatus of claim 5, further comprising laser cavity means, whereby the output of the laser cavity means is controlled by the film when the film is used as a reflective element in the laser cavity.

15. The apparatus of claim 5, further comprising a transparent quarter wave retardation plate in close proximity to the first surface, whereby linearly polarized light incident on the transparent quarter wave retardation plate is controllably reflected.

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16. A method of making a light controlling film, the film having a first surface and a second surface, comprising:

applying a mixture of high molecular weight polymeric material  
and low molecular weight polymeric material on a surface which produces  
a CLC order in the mixture; and crosslinking the high molecular weight  
polymeric material so that the low molecular weight material significantly  
diffuses throughout the film and remains distributed in a non uniform  
fashion across the film from the first surface to the second surface;

wherein light having a first polarization and a broad bandwidth  
incident on the first surface is substantially reflected from the film, and  
wherein light having a second polarization and the broad bandwidth  
incident on the first surface is not substantially reflected from the film,  
and wherein an electric field impressed in the film substantially decreases  
the reflection of light of the first polarization and broad bandwidth.

17. The method of claim 16, wherein the step of crosslinking takes  
place in a time t1 long compared to the time t2 in which the low  
molecular weight material can significantly diffuse.

18. The method of claim 17, wherein the step of crosslinking takes  
place includes irradiation of the film by low intensity ultraviolet  
radiation.

19. The method of claim 18, wherein the step of crosslinking takes  
place includes irradiation of the film by high intensity ultraviolet  
radiation having a radiation intensity of less than 1 mw/cm<sup>2</sup>.

20. The method of claim 17, wherein the step of crosslinking takes  
place includes irradiation of the film by high energy electrons where  
the electron where the electron energy deposition varies substantially  
throughout the film.

21. The method of claim 17, wherein the step of crosslinking takes place includes irradiation of the film by light which is substantially nonuniformly absorbed throughout the film.

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22. The method of claim 17, wherein the step of crosslinking takes place includes heating the film substantially nonuniformly across the film.

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23. A system for controlling EM radiation comprising:  
a substrate;  
a single layer of material on the substrate, the material reflecting the electro-magnetic (EM) radiation, the reflected EM radiation being polarized, the reflected EM radiation having a broad bandwidth;  
an electric field generator for generating a variable electric field in the layer of material; and  
a controller for controlling the electric field generator;  
whereby the controller controls the electric field generator to generate a field in the layer of material and whereby the reflected EM radiation changes in response to the change of the electric field.

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24. A switchable single layer reflective polarizer for reflecting light of a first polarization, the single layer reflective polarizer having a non linear distribution of polarized light reflecting molecules such that the bandwidth of polarized light reflected from the reflective polarizer is very broad, and wherein an electric field impressed across the single layer changes the reflectivity of the single layer.

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25. The switchable reflective polarizer of claim 24 in combination with

an additional switchable reflective polarizer reflecting the opposite polarization, whereby the bandwidth of both polarizations of light reflected from the combination is very broad, and whereby the reflectivity of light in the broad bandwidth may be controlled by the  
5 electric field.

26. The switchable reflective combination of claim 25 controllably reflecting visible light in combination with a broad band infra-red reflecting and visible transmitting component, whereby visible light may  
10 be controllably transmitted and infra-red light may be reflected.

27. The switchable reflective combination of claim 25 controllably reflecting visible light in combination with a switchable reflective combination of claim 25 controllably reflecting infra-red light, whereby visible light may be controllably transmitted and infra-red light may be  
15 controllably transmitted.

28. A light controlling film, the film having a first surface and a second surface, comprising:

20 a polymerized polymer network, comprising:  
a crosslinked high molecular weight polymeric material; and  
a low molecular weight cholesteric liquid crystal (CLC) material,  
wherein the high molecular weight and the low molecular weight form a  
material having cholesteric liquid crystal (CLC) order, the CLC order  
25 oriented with respect to the first and the second surfaces, and  
wherein light having a first polarization and a first bandwidth  
incident on the first surface is substantially reflected from the film, and  
wherein light having a second polarization and the first bandwidth  
incident on the first surface is not substantially reflected from the film,

and wherein an electric field impressed in the film substantially changes  
the first bandwidth of reflection of light  
having the first polarization.

5        29. The light controlling film of claim 28, wherein the crosslinked high  
molecular weight polymeric material is less than 20% by weight of the  
film.

10      30. The light controlling film of claim 29, wherein the crosslinked high  
molecular weight polymeric material is less than 15% by weight of the  
film.

15      31. The light controlling film of claim 30, wherein the crosslinked high  
molecular weight polymeric material is less than 12% by weight of the  
film.

20      32. The light controlling film of claim 28, wherein the proportion of  
crosslinked high molecular weight material to low molecular weight  
material is substantially constant across the film from the first surface to  
the second surface.

25      33. The light controlling film of claim 28, further comprising a first  
electrically conducting material adjacent to the first surface, the first  
electrically conducting material for impressing an electric field in the film,  
the first electrically conducting material transmitting light having the first  
bandwidth.

34. The apparatus of claim 33, further comprising a second electrically  
conducting material adjacent to the second surface, wherein a voltage

applied between the first and the second electrically conducting material impresses an electric field on in the film.

5       35. The apparatus of claim 34, wherein the second electrically conducting material transmits light having the first bandwidth.

36. The apparatus of claim 34, wherein the first polarization is a circular polarization.

10      37. The apparatus of claim 36, further comprising a transparent quarter wave retardation plate in close proximity to the first surface, whereby linearly polarized light incident on the transparent quarter wave retardation plate is controllably reflected.

15      38. The apparatus of claim 33, further comprising a means for applying an electric field in the film, the electric field varying spatially over the first surface, whereby polarized light is controllably reflected for display purposes.

20      39. The apparatus of claim 33, further comprising optical communication means, whereby the bandwidth of light in the optical communication means is controlled.

25      40. The apparatus of claim 33, further comprising means for directing light on to the first surface, and means for receiving light from the first surface, whereby polarized light with a controllable bandwidth produced in the means for receiving light.

41. The apparatus of claim 33, further comprising laser cavity means,

whereby the bandwidth of the light output of the laser cavity means is controlled by the film when the film is used as a reflective element in the laser cavity.

5        42. The apparatus of claim 33, further comprising a transparent quarter wave retardation plate in close proximity to the first surface, whereby linearly polarized light incident on the transparent quarter wave retardation plate is controllably reflected.

10      43. A method of making a light controlling film, the film having a first surface and a second surface, comprising:

applying a mixture of high molecular weight polymeric material and

low molecular weight polymeric material on a surface which produces a CLC order in the mixture; and

crosslinking the high molecular weight polymeric material so that the low molecular weight material does not significantly diffuse and remains uniformly distributed in the film;

20      wherein light having a first polarization and a first bandwidth incident on the first surface is substantially reflected from the film, and wherein light having a second polarization and the first bandwidth incident on the first surface is not substantially reflected from the film, and wherein an electric field impressed in the film substantially increases the first bandwidth of reflection of light having the first polarization.

25      44. The method of claim 43, wherein the step of crosslinking takes place in a time  $t_1$  short compared to the time  $t_2$  in which the low molecular weight material can significantly diffuse.

45. The method of claim 44, wherein the step of crosslinking takes place includes irradiation of the film by high intensity ultraviolet radiation.

5 46. The method of claim 45, wherein the step of crosslinking takes place includes irradiation of the film by high intensity ultraviolet radiation having a radiation intensity of greater than 0.1 watts/cm<sup>2</sup>.

10 47. The method of claim 43, wherein the step of crosslinking takes place includes irradiation of the film by high energy electrons where the electron where the electron energy deposition is substantially constant throughout the film.

15 48. The method of claim 43, wherein the step of crosslinking takes place includes irradiation of the film by light which is substantially uniformly absorbed throughout the film.

20 49. The method of claim 43, wherein the step of crosslinking takes place includes heating the film substantially uniformly throughout the film.

50. A system for controlling unpolarized electromagnetic (EM) radiation comprising:  
a substrate;  
25 a single layer of material on the substrate, the material reflecting the electro-magnetic (EM) radiation, the reflected EM radiation being polarized, the reflected EM radiation having a bandwidth;  
an electric field generator for generating a variable electric field in the layer of material; and

a controller for controlling the electric field generator;  
whereby the controller controls the electric field generator to  
generate a field in the layer of material and whereby the bandwidth of the  
reflected EM radiation changes in response to the change of the electric  
field.

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51. A switchable reflective polarizer for reflecting light of a first  
polarization, wherein the bandwidth of polarized light reflected from  
the reflective polarizer may be changed from a broad bandwidth to a  
10 narrower bandwidth by the application of an voltage to the reflective  
polarizer.

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52. The switchable reflective polarizer of claim 51 in combination with  
an additional switchable reflective polarizer reflecting the opposite  
15 polarization, whereby the bandwidth of all light reflected from the  
combination may be changed from a broad bandwidth to a narrower  
bandwidth by the application of an voltage to the reflective polarizer.

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53. The switchable reflective combination of claim 52 controllably  
reflecting visible light in combination with a broad band infra-red  
reflecting and visible transmitting component, whereby visible light may  
20 be controllably transmitted and infra-red light may be reflected.

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54. The switchable reflective combination of claim 52 controllably  
reflecting visible light in combination with a switchable reflective  
combination of claim 25 controllably reflecting infra-red light, whereby  
visible light may be controllably transmitted and infra-red light may be  
25 controllably transmitted.

55. A single layer polarizing film having a very wide bandwidth which is switchable.

56. A switchable reflecting polarizing filter having a very wide bandwidth which is controllable by an electric field.

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70. A switchable reflective film having little variation in the reflectivity outside of the reflective bandwidth of the film.

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58. A "smart window" using a polarizing reflective film having a very wide bandwidth.

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59. A smart window using a polarizing reflective film having a very wide bandwidth combined with a reflective multilayer polymer film having a very wide bandwidth.

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69. A smart window using a polarizing reflective film having a very wide bandwidth combined with a reflective multilayer polymer film having little variation in the reflectivity outside of the reflective bandwidth of the film.

70. A smart window using a polarizing reflective multilayer polymer film having a very wide bandwidth combined with a light scattering layer for further control of transmitted light.

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62. A reflective polarizing film having a bandwidth which is controllable by an electric field.

63. A smart window using a polarizing reflective film having a very wide bandwidth which is controllable by an electric field.

5           64. An electrically-switchable family of infrared reflective polarizers and filters, based on the remarkable properties of cholesteric liquid crystals (CLCs), having far-reaching dual-use aerospace and window-glazing applications.

10          65. An electrically controllable polarizer that can be remotely controlled and involves no moving parts, to active-solar-control window glazings having the unheard-of property of infrared switchability while maintaining total visible transparency.

15          66. A near-infrared switchable polarizer embodied in a remote-controlled optical component.

20          67. A electrically-switchable infrared reflective polarizer capable of switching from broad-to-narrow band reflective operation over the IR band.

68. A electrically-switchable infrared reflective polarizer, wherein its rise time is about at least 14.5 ms and its fall time is about at least 8.5 ms.

25          71. A electrically-switchable infrared reflective polarizer capable of switching from narrow-to-broad band reflective operation over the IR band.

72. An electrically-tunable infrared reflective polarizer.

71. An electrically switchable IR reflector based on an electrically

switchable broadband reflective polarizer that operates in the IR region from 780nm to 4 microns.

5        73. A left and right-handed CLC based switchable broadband polarizers that operate in the IR region from 780nm to 4 microns.

10      74. A field-switchable broadband reflective polarizer operable in the NIR spectral region.

15      75. A field-switchable broadband reflective polarizer operable in the spectral region from 700 to > 1000 nm, and having a polarizing bandwidth and extinction ratio which are changeable via an applied electric field.

20      76. A method of optimizing the performance of such electro-optical structures in terms of extinction ratio, overall reflectivity, and reflection spectral cutting-off edge.

25      77. A material recipe for making the switchable, broadband-to-narrow-band polarizers and which enables further expansion of the polarizer bandwidth, shift to longer wavelengths, and increase the extinction ratio to the desired level.

78. A method of making such electrically-switchable IR reflective polarizers, using liquid crystal polymeric compounds having different pitch, cross-linking density, and polymerization rate.

79. An electrically-controllable narrow-band reflective polarizer which undergoes a shift in reflection band, rather than a broadening in bandwidth when a DC voltage is applied.

5 80. A method of precisely electrically tuning the CLC center wavelength by applying an electric field, without affecting the other specifications of the polarizer, such as polarization, extinction ratio, and bandwidth.